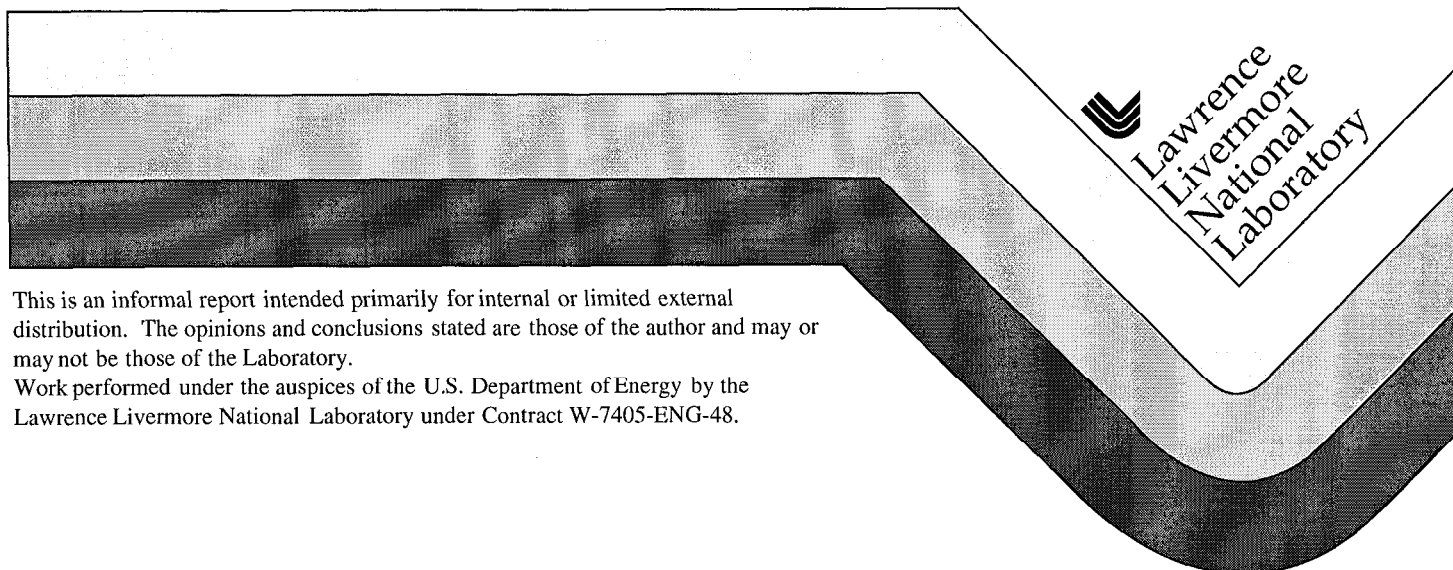


Pulse Width Dispersion at 351-nm in Single Fibers with Diameters of 100 and 435 Microns, and in a Bundle of 19 Fibers

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FROM:

Calvin Thompson, Walter Sell, Roger Griffith, John Hollis and
D. Milam *W.S.*

SUBJECT: Pulse width dispersion at 351-nm in single fibers with diameters of 100 and 435 microns, and in a bundle of 19 fibers.

1. General comments:

Pulse width broadening at 351-nm was measured in two single fibers (core sizes 100 and 435 μm), and in a 32-m bundle of 19 each 50- μm -core fibers from preform #24. All of the fiber was from the Vavilov State Optical Institute at St. Petersburg, Russia. Glen Phillips assembled the bundle at LLNL.

SMA connectors were mounted to both ends of each test fiber. One SMA connector was attached to a UV Launch Optic assembly that was used to inject light into the fibers. The other was attached to a bulkhead SMA connector that held the output end of the fiber in close proximity to the slit of a streak camera, LLNL#7, which has an S-1 photocathode. An S-20 camera was not available.

Pulse broadening in the fiber was compared to that in one of two types of comparison paths. One, which we designate AirPath, was simply an air path of appropriate length. The other, designated Composite, was an air path plus a 1-m length of 100- μm -core, thin-clad fiber which had SMA connectors on each end. The fiber segment in the Composite path was filled by a second UV Launch Optic assembly (optical configuration, AAA98-105057).

2. Results.

2.A. 10-m length of 435- μm -core single fiber.

For test#1, the reference pulse propagated over an AirPath. Examples of the waveforms are shown in Fig. 1. Five streaks were reduced. Pulse broadening ranged from -0.05 to 4.0 ps, and the calculated dispersions ranged from 0 to 1.9 ps/m.

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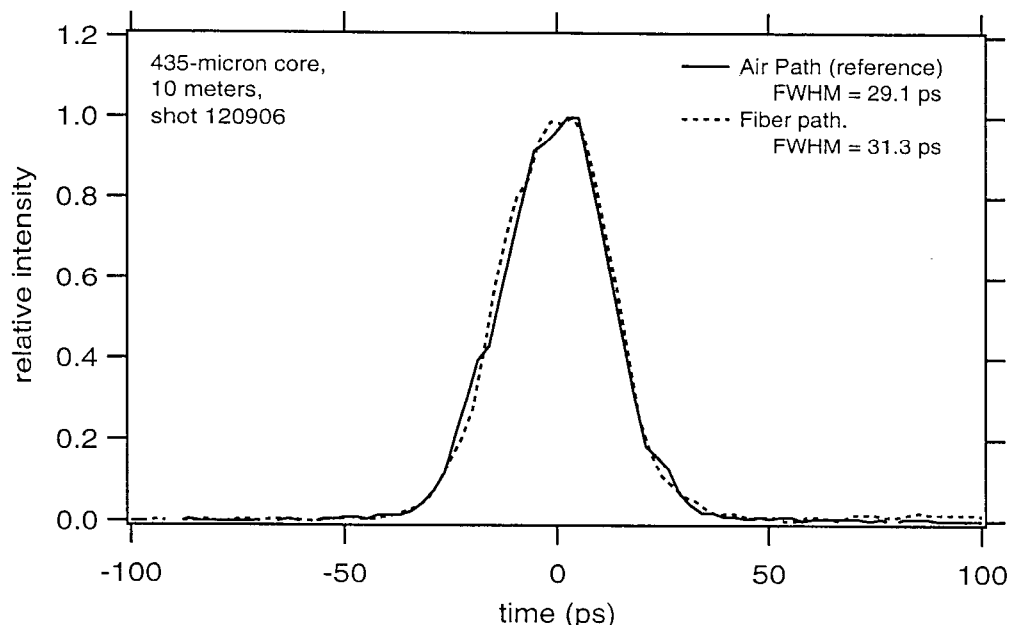


Fig. 1. Pulse broadening--large fiber vs air path.

For test#2, we used a Composite reference path: Example waveforms are in Fig. 2. Three streaks were reduced. Pulse broadening ranged from 5.7 to 7.1 ps, and dispersion ranged from 1.9 to 2.0 ps/m.

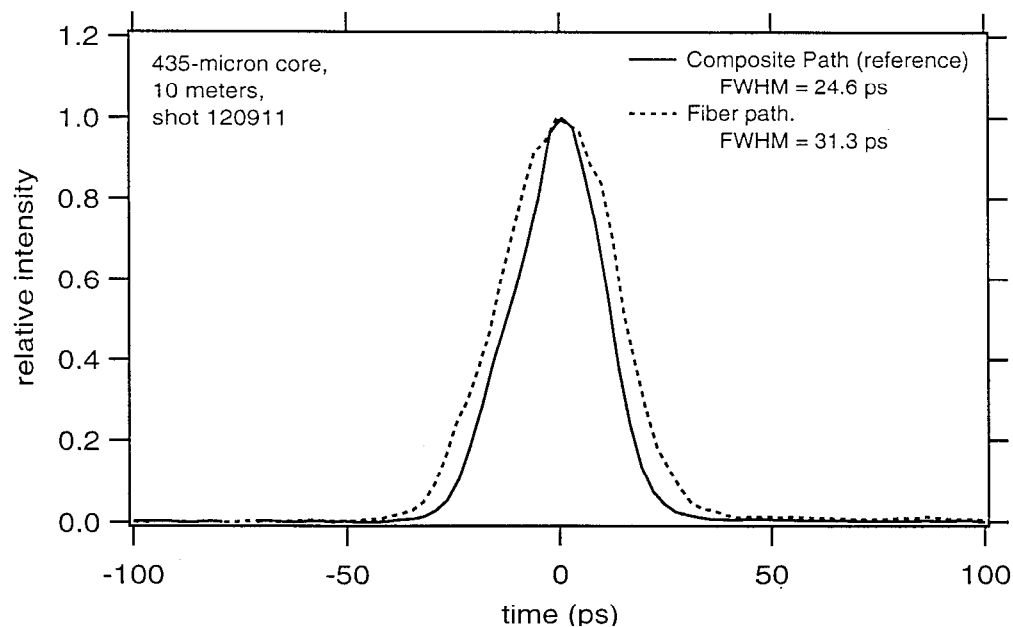


Fig. 2. Pulse broadening: large fiber vs Composite path. In Figs. 1 and 2, durations of the fiber-path pulse are the same, but the reference pulse was shorter when it propagated over the Composite path.

Conclusions:

These are very favorable results. The magnitude of the pulse broadening in the 10-m length of the 435- μm fiber was small and comparable to the uncertainty in the measurement. However, the calculated temporal dispersion is 1 ± 1 ps/m, so broadening might be an issue in a longer fiber. We will modify contract #B347674 to include acquisition of a longer length of this fiber for testing.

A secondary conclusion concerns the question of whether use of a UV Launch Optic assembly significantly contributes to pulse broadening. Apparently, the answer is no. We draw this conclusion by inverting our previous line of reasoning. Now, we use the broadening in the fiber path as a standard to allow comparison of the pulse broadenings in the AirPath and the Composite paths. Look again at Figs. 1 and 2. For both shots, the FWHM for the fiber path was 31 ps. For the AirPath (Fig. 1) the width was 29 ps, and for the Composite path, which contained a Launch Optic, the width was 25 ps. This trend was true for the eight streaks that were reduced. The mean differential in values of FWHM was 2.8 ps for 5 tests that compared the AirPath with the fiber path, and 6.5 ps for 3 tests that compared the Composite and fiber paths. The data base is too small to support an assertion that use of the Launch Optic assembly reduces the measured pulse width, but we can be reasonably certain that the assembly does not contribute to broadening.

2.B. Bundle of 19 each 50- μm -core fibers.

Glenn Phillips assembled a 32-m bundle of 19 fibers, and attached an SMA connector to each end. Individual fibers in the bundle, measured using an optical time domain reflectometer, had lengths that were identical to within 4 mm which can be traversed by light in about 20 ps. Light was injected into the bundle by a UV Launch Optic assembly. The reference pulse propagated over an AirPath, and was gently focused through the hole in the SMA bulkhead connector onto the slit of the streak camera. An example of the data is shown in Fig. 3.

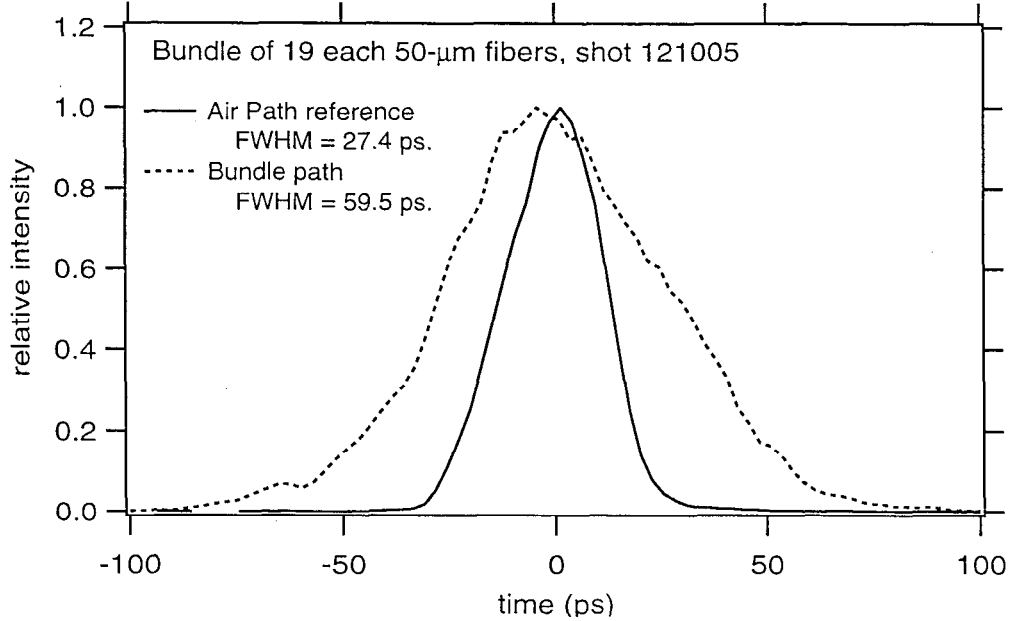


Fig. 3. Pulse broadening: Bundle of 19 fibers vs the Composite reference path.

For the seven streaks that were reduced, the mean value of the FWHM was 26 ± 1.4 ps for the reference pulse, and 55 ± 6.4 for the pulse that propagated through the bundle. Broadening by the bundle has two components, dispersion by the fibers themselves and bundle dispersion. A fiber dispersion of 26 ± 6 ps for the 32-m length is obtained from the dispersion, 0.8 ± 0.2 ps/m, that we previously measured for a 50-μm-core fiber from this preform [1]. If we use the equation

$\tau_{\text{out}}^2 = \tau_{\text{in}}^2 + \tau_f^2 + \tau_b^2$ to relate the measured input and output widths, τ_{in} and τ_{out} , to the fiber and bundle dispersions, τ_f and τ_b , we obtain $\tau_b = 39 + 11 - 17$ ps, where the stated uncertainty is the total range that is allowed by the uncertainties in τ_{out}^2 , τ_{in}^2 , and τ_f^2 .

The dispersion of about 20 ps that was expected from the 4-mm accuracy of the 32-m lengths in the bundle is less than the smallest experimental value in the uncertainty range, 22 ps. To date, this discrepancy has not been resolved.

However, this bundle does meet the NIF bundle dispersion criteria of 50 ps and did not exhibit the pre and post foot pulses, or the offset trailing pulses, of the commercially fabricated bundles. [1] To be fair, the individual fibers of the commercial bundles were not optically measured – only a mechanical measurement was made of the length of the individual fibers. The purpose of this earlier bundling effort was to determine if such a less precise type of construction could be used to reduce the anticipated high bundling costs if optical measurement of each fiber were required.

2.C. Thin-clad, 100- μm -core single fiber.

Pulse broadening in a 13.6-meter length of this fiber was compared to that for a Composite reference path of appropriate length. The data are visually similar to those in Figs. 1 and 2, so it is not necessary to present an example.

Twenty streaks were reduced. The mean FWHM was 26 ± 1.26 ps for the reference pulse, and 29 ± 1.30 ps for the pulse that propagated through the fiber. The mean difference was 3.6 ± 1.3 ps, and the calculated pulse width dispersion is $0.94 + 0.2 - 0.4$ ps/m. This result cannot be distinguished from the dispersion, 0.8 ± 0.2 ps/m, that we previously measured in a thick-clad, 100- μm -core fiber [1].

We attempted to measure dispersion in 25-m and 35-m lengths of the thin-clad, 100- μm -core fiber, but were not able to obtain adequate signal. Because of this difficulty, we measured the attenuation separately. The 351-nm beam from an Ar⁺ laser was lens coupled into the fiber. Near to the launch end, several turns of the fiber were wound on a small diameter mandrel to mix the modes. The cut-back technique was used to measure transmission, starting with a length of 50 m. Figure 4 shows the data; a least-squares fit calculates the attenuation as 468 dB/km. The Russian measurement for this fiber was ~ 150 dB/km. At the present time we do not have an explanation for this discrepancy.

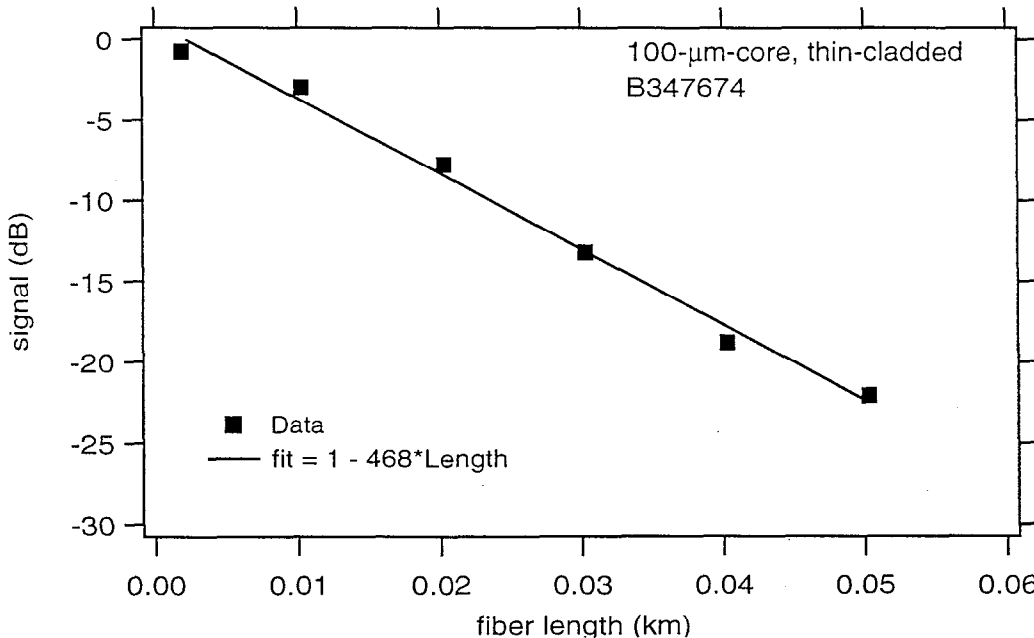


Fig. 4. Fiber attenuation (468 dB/km) of the 100 μm core, thin-clad fiber.

3. References.

1. Memo to Distribution, "Measurements at 351-nm of temporal dispersion in fibers," David Milam, Calvin Thompson, Walter Sell, and Roger Griffith, NIF # 00116173, WBS 1.7.2.2, November 4, 1998.